MEAN FIVE-DAY PRESSURE PATTERN OF THE GREAT ATLANTIC COAST STORM, MARCH 1962

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ABSTRACT

A mean sea level pressure map is drawn for the North Atlantic Ocean for the period of the Atlantic Coast storm of March 5–9, 1962 and anomaly and normalized departure charts are presented. A comparison is made with the January 8–12, 1956 storm during which some of the greatest pressure anomalies associated with severe extratropical coastal storms of the 20th century occurred. It is noted that in the typical northeaster a ridge usually extends east-southeastward or southeastward over the North Atlantic Ocean from a High located over eastern Canada and Labrador. The ridge was very weak in the March 1962 situation and the resulting pressure pattern produced winds with easterly components of an unusually long fetch from the British Isles to the coastal waters of the United States.

Return periods or mean recurrence values were computed, from an extreme value probability analysis based on 17 years of 5-day mean sea level pressure grid point data, for the intensity of cyclones and anticyclones associated with the March 1962 and January 1956 storms. The extreme easterly flow was computed between 35° and 45° N. from 55° to 75° W. and return periods of 18 years and 11 years were found for the January 1956 and March 1962 storms, respectively.

1. INTRODUCTION

The Great Atlantic Coast Storm of March 1962, which took 33 lives and caused about $200,000,000 in tidal damage [1], has been claimed to be the most damaging extratropical east coast storm of this century. The coincidence of high storm surges and waves in conjunction with high astronomical tides, in a concentrated region of valuable property near the beaches, resulted in severe beach erosion and substantial property damage. It is felt that the slow movement of this severe storm with tidal damage occurring over several successive high tides was one of the major factors contributing to the damage and that such a synoptic situation should be reflected in the 5-day mean pressure pattern. Therefore it was decided to make a statistical analysis which took into consideration the pressure pattern alone and neglected the effect of the astronomical tides to determine just how unusual this type of synoptic situation is. Fortunately, readily available 5-day mean climatic data in various forms make this type of statistical treatment possible.

2. FIVE-DAY MEAN SEA LEVEL PRESSURES AND ANOMALIES

One such source is Lahey, Bryson, and Wahl's [2] atlas of 5-day normal sea level pressure charts. This atlas presents 5-day charts of normal sea level pressure, standard deviation, and pressure change between successive 5-day periods between latitudes 30° and 65° N. for a 20-yr. period of 1230 GMT charts. In order to compare the March storm with these charts, a mean chart for the 5-day period March 5–9, 1962, covering the most intense stages of the storm, was constructed and is shown in figure 1. This mean chart was compiled from the National Meteorological Center's 1200 GMT Northern Hemisphere Sea Level Charts for the period using five-degree grid point data.

The most important feature of this chart is the trough which extends from the midocean Low of 990 mb. west-southwestward and then westward over the Middle Atlantic States enclosing the coastal Low of 1001 mb. off Cape Hatteras. The midocean Low, the circulation of which covers the entire North Atlantic, was produced by a slow-moving and intense cyclone which, by virtue of its relatively short distance ahead of the coastal Low and its easterly track between 40° and 45° N., played a major role in setting up westward-moving wave trains across the northern latitudes. In addition, it prevented ridging southeastward across the Grand Banks into the Atlantic which usually separates intense extratropical cyclones of this type. Of equal significance on figure 1 is the unusual high pressure area over the Arctic regions of Greenland and eastern Canada with a north-south ridge along the 70th meridian. The orientation of the above ridge and trough produced strong winds with easterly components from the British Isles to the Middle Atlantic Coast and replaced the normal westerly flow at these latitudes. South of the trough line abnormally strong westerlies prevailed over much of the region usually under the influence of the northeast trades.

Since the 5-day normal pressure charts [2] were for the periods March 2–6 and 7–11, it was necessary to interpolate between the above dates in order to determine the

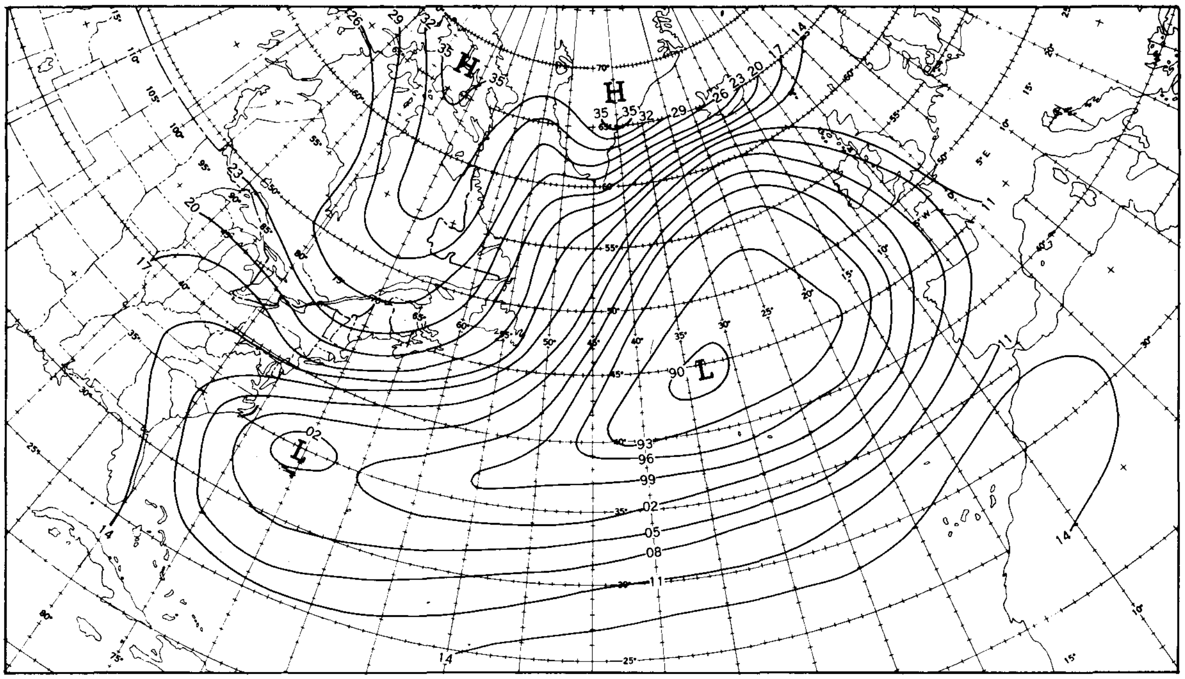

FIGURE 1.—Five-day mean sea level pressure distribution (mb.), March 5–9, 1962.

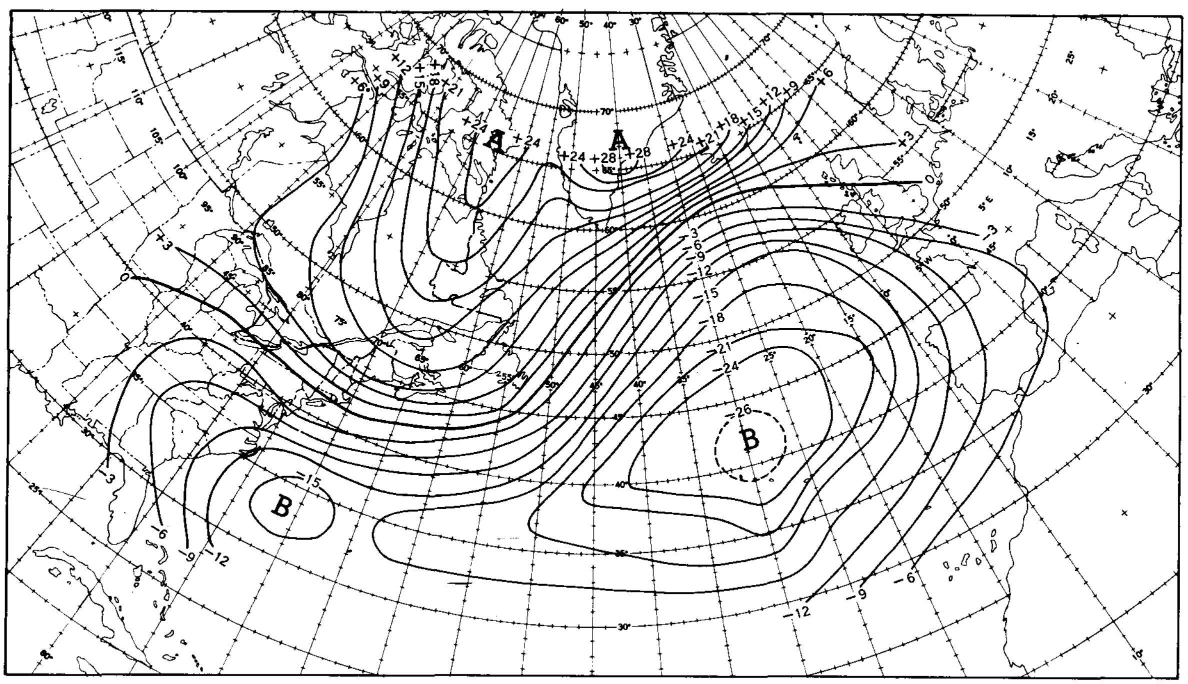

FIGURE 2.—Pressure departure from normal (mb.), March 5–9, 1962.

departures for the March 5–9 period and normalize these. Figure 2 shows these pressure anomalies. The centers of maximum departure nearly coincide with the Lows and Highs of the mean chart. The maximum negative anomalies are −26.2 mb. near 40° N., 30° W., and, for the coastal Low, −16.4 mb. at 35° N., 70° W. Positive anomalies reached +28.5 mb. over the western Denmark Strait and +25.8 mb. over southern Baffin Island. Departures might have been greater farther north, but the atlas [2] does not cover these areas. The standard deviations, interpolated from the atlas, were used to normalize these and the resulting pattern is shown on figure 3. The areas with the highest absolute departures from the normal expressed in terms of standard deviation closely coincide with the areas of maximum departures except for some southward displacement in the low pressure areas.

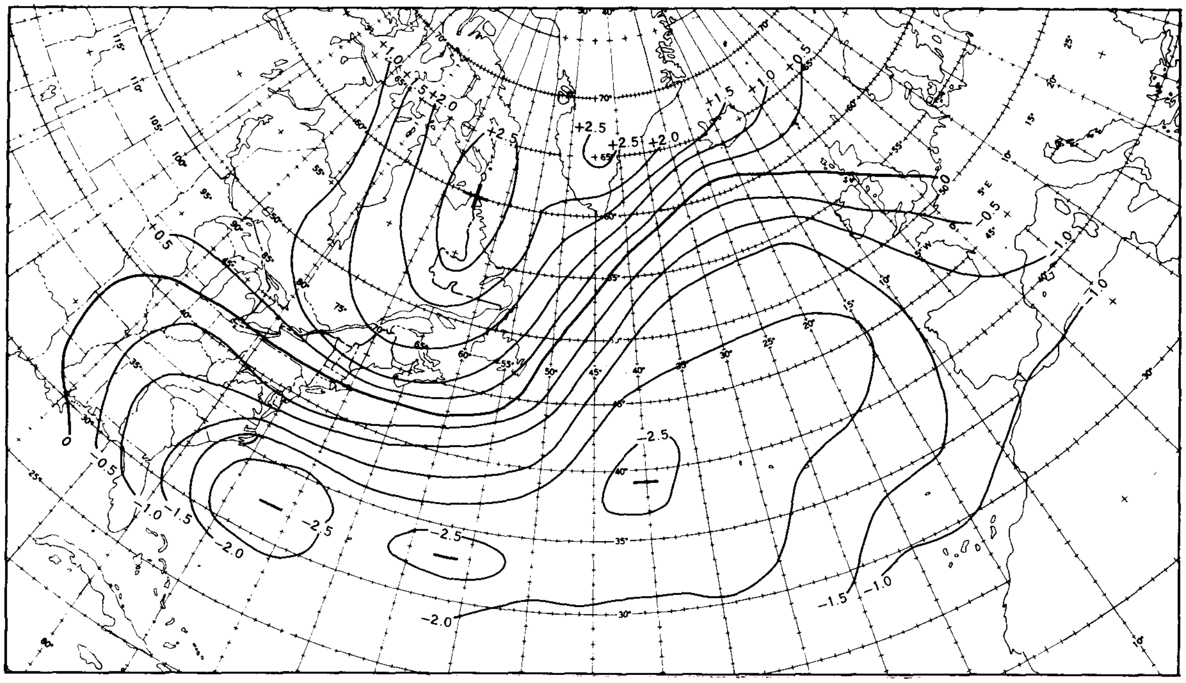

Figure 3.—Normalized pressure departures (in standard deviations), March 5–9, 1962.

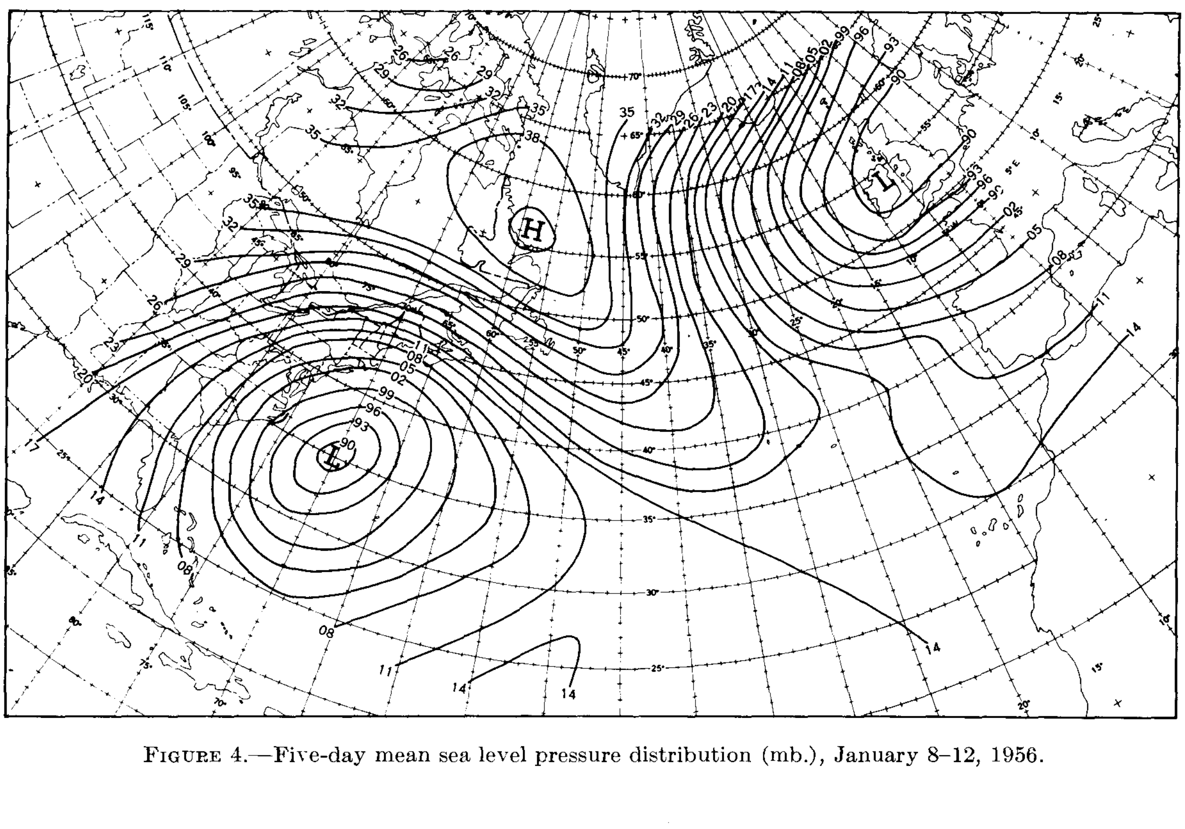

Figure 4.—Five-day mean sea level pressure distribution (mb.), January 8–12, 1956.

The highest significance was found in the region southeast of Cape Hatteras near 33° N., 70° W. where the value was −2.84 standard deviations. The midocean Low was only slightly less significant with a normalized value of the departure of −2.68 standard deviations. Over the Arctic region the maximum value was +2.76 standard deviations near the Labrador coast at 60° N., 65° W.

The synoptic situation during past coastal storms was examined, and one case—the January 8–12, 1956 case—was found to be outstanding in respect to such pressure anomalies [3, 4]. The 5-day mean pressure chart was constructed for this period (fig. 4). The chart shows a low pressure area of 989 mb. at 35° N., 70° W. off Hatteras and a high pressure area of 1041 mb. at the Labrador coast

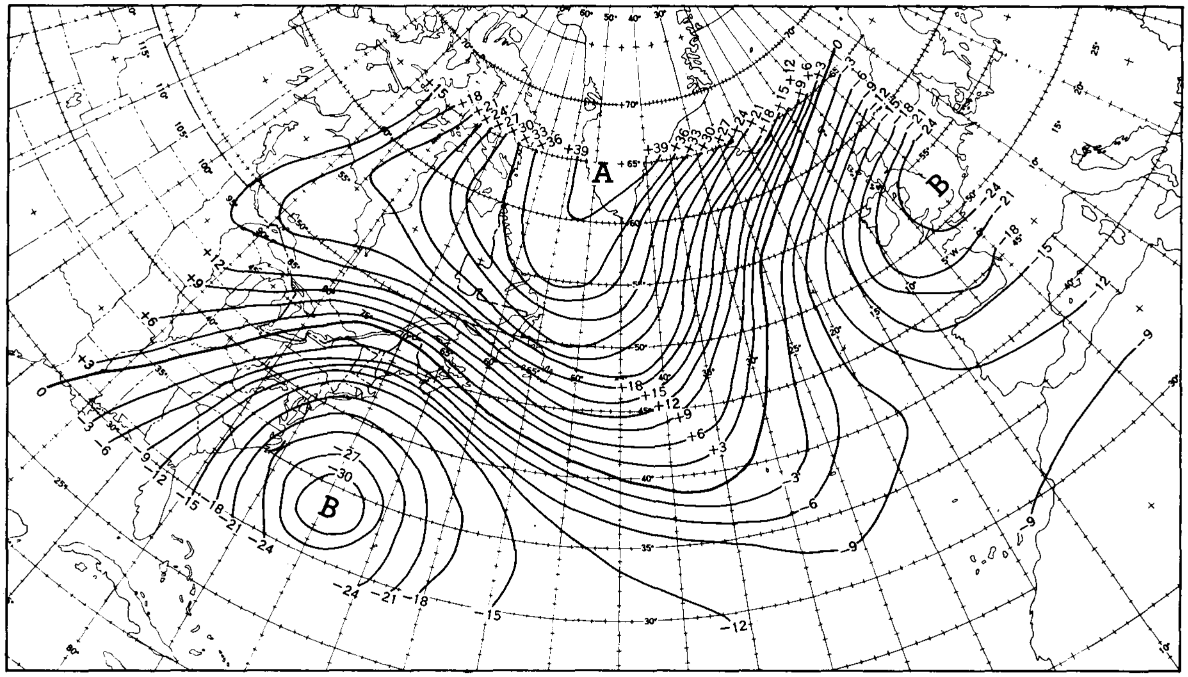

FIGURE 5.—Pressure departure from normal (mb.), January 8–12, 1956.

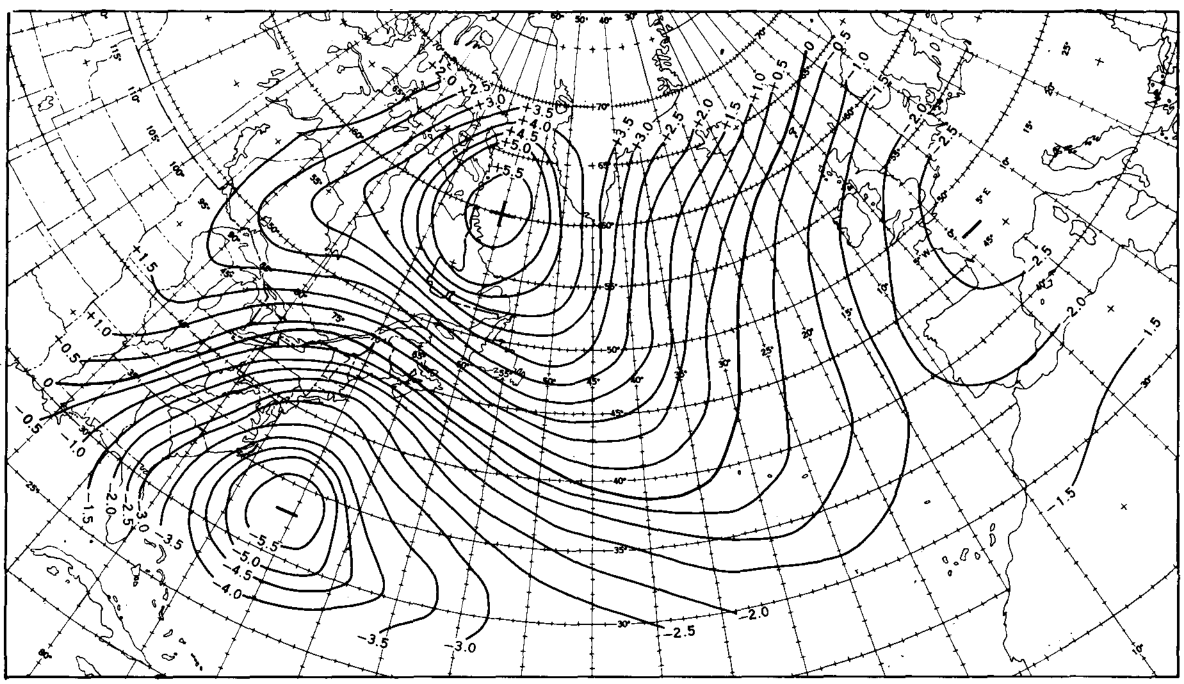

FIGURE 6.—Normalized pressure departures (in standard deviations), January 8–12, 1956.

near 55° N., 60° W. with a strong ridge extending southeastward across midocean toward the Azores separating the Hatteras Low from the preceding Low which already had reached the British Isles. This ridge is generally present in coastal storms of this type but was nearly absent in the March 1962 storm. The pressure gradient between the Labrador High and the Hatteras Low was quite a bit steeper during the January 1956 period, but a large portion of this steep gradient was located over land over the Canadian Maritime Provinces. The gradient between Cape Cod and the central region of the Hatteras Low, which is some measure of the wind toward the exposed Middle Atlantic Coast, amounted to 14 mb. in January 1956 against 18 mb. in March 1962.

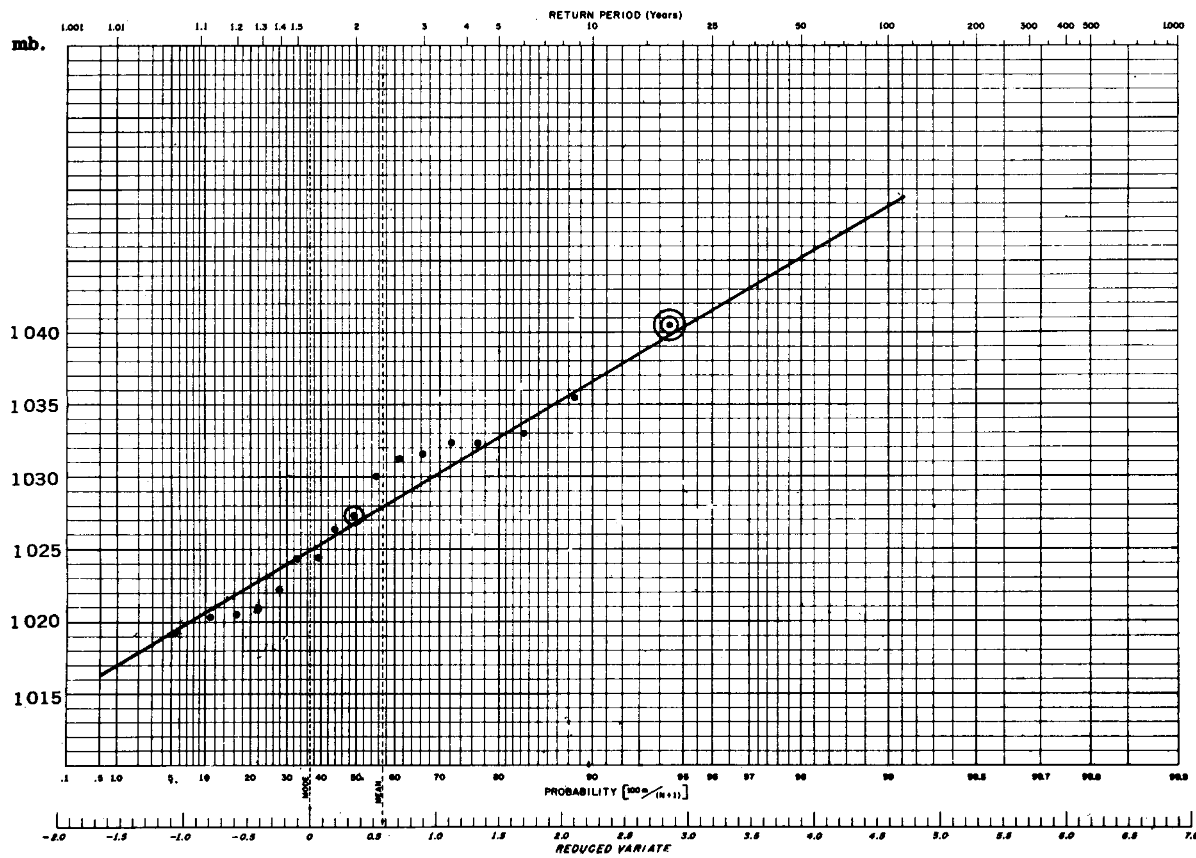

FIGURE 7.—Probability distribution of the annual extremes of 5-day mean maximum sea level pressure values (1946–62) at 60° N., 60° W. Circled point = March 6–10, 1962; double-circled point, January 7–11, 1956.

Figure 5 depicts the departures from normal in the January 1956 case. Values as large as −33 mb. were found off Hatteras and +40 mb. near the southwestern coast of Greenland. In terms of standard deviation, (fig. 6), values of −5.86 were obtained off Hatteras and of +5.58 in the Davis Strait, the same two general areas where the significant departures were found in March 1962.

3. EXTREME PROBABILITY ANALYSIS

Since these two cases are extremes, as shown by the high absolute values of the normalized departures, and their values would therefore not necessarily be normally distributed, it was decided to apply an extreme probability analysis to the data. This type of analysis gives return period or mean recurrence values on an annual basis while the other method applies only to the specific 5-day periods analyzed. The proper estimate of the probability of occurrence comes from considering only the extreme values each year. This of course makes it necessary to use an extreme value distribution. The Fisher-Tippet Type I distribution has been shown by Thom [5] to give the best results for many climatological elements involving unbounded extreme values. This distribution has also been widely applied by Gumbel [6].

Fortunately, grid point data of 5-day mean surface pressures were available from Extended Forecast Branch of the Weather Bureau for the 17-yr. period 1946–62. These grid point data were compiled twice a week from two observations a day. The extreme value data were chosen for the months October 15 through April 15 to include the period of most intense extratropical cyclone development. Extreme value dates were checked with Cry et al. [7] and those caused by tropical cyclones were eliminated. The grid point data were available in a staggered fashion along every 5° of latitude at every 10° longitude; i.e. for 35° N. at 75° W., 65° W., 55° W., and for 40° N. at 70° W., 60° W., 50° W., etc.

The areas off Hatteras and the Labrador coasts which had such large significant departures in the previous analysis were selected and the grid points chosen were 60° N., 60° W. for the high pressure and 35° N., 75° W. for the low pressure. The periods corresponding to the twice weekly computed grid point data for the two storms were March 6–10, 1962 and January 7–11, 1956. This is a shift of one day in the periods used in the previous analysis.

The highest pressure for each of the 17 years was selected from the grid point data at 60° N., 60° W. and plotted on extreme probability paper as shown in figure 7. A Lieblein

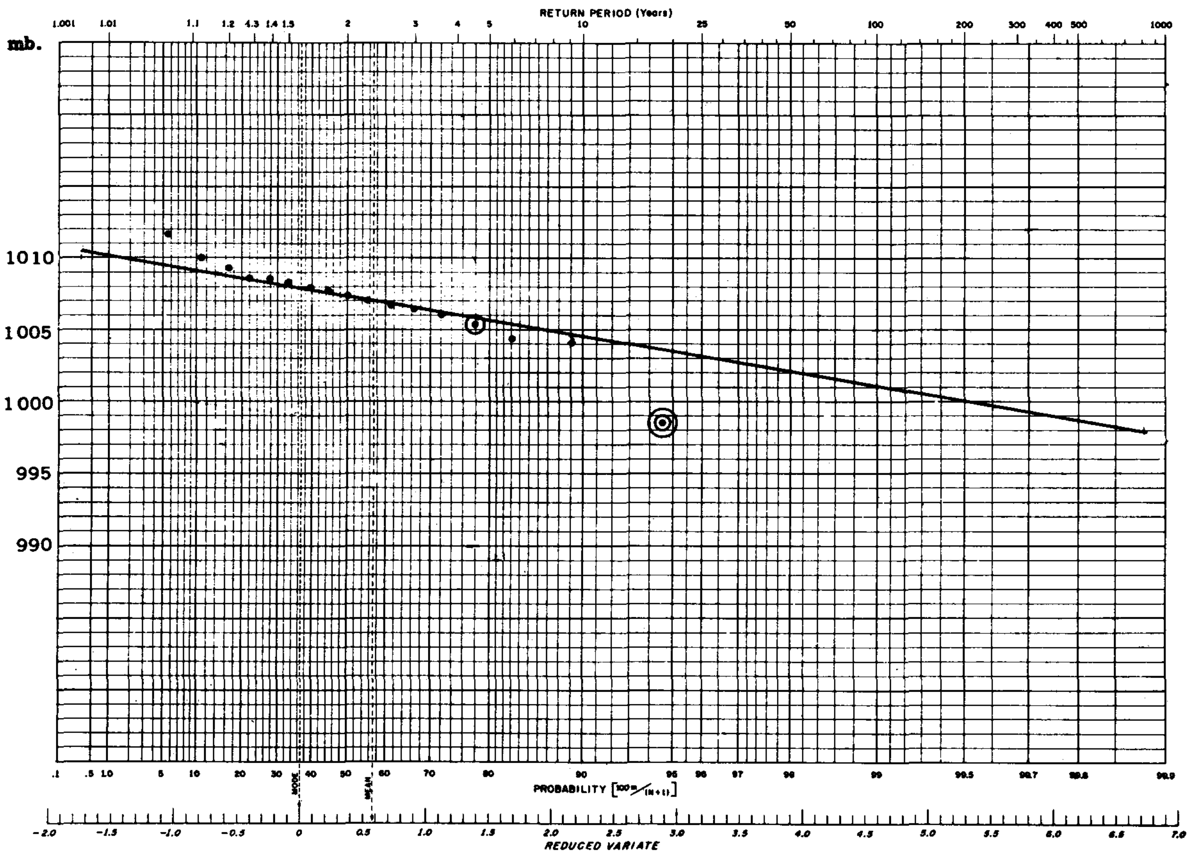

FIGURE 8.—Probability distribution of the annual extremes of 5-day mean minimum sea level pressure values (1946–62) at 35° N., 75° W. Circled point = March 6–10, 1962; double-circled point, January 7–11, 1956.

fitting procedure described by Thom [5] was utilized in order to construct the line of best fit. The high pressure value associated with the January 1956 storm, 1040.5 mb., was the maximum of the extreme values obtained for this grid point. Its return period is 20 years. The corresponding value for the March 1962 anticyclone, 1027.6 mb., has a return period of a little over 2 years.

Similar analysis was performed for the low pressure values at 35° N., 75° W., and is shown in figure 8. Again

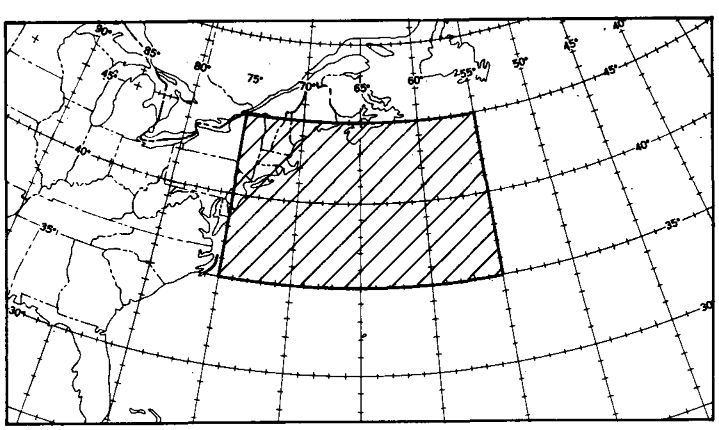

FIGURE 9.—Area over which extreme easterly flow was computed for each year 1946–62.

the January 1956 value, 998.4 mb., was by far the most outstanding with a return period of about 600 years. The March 1962 low pressure value of 1005.4 mb. showed a return period of 5 years.

It should be noted that in both of these two storms the high and low pressures were extremes for the year. The probability of extreme values of high pressure occurring to the north simultaneously with low pressure to the south are not independent of each other and therefore their individual probabilities cannot be multiplied. To determine the relationship between simultaneous occurrences of high pressure to the north and low pressure to the south, or the intensity of the pressure gradient, it was decided to measure the extreme easterly flow for each year between 35° N. and 45° N. from 55° W. to 75° W. This area is shown in figure 9. It includes the Atlantic coast north of Hatteras and south of the Canadian Maritime Provinces eastward to the Grand Banks. It is felt that the easterly flow in this zone, due to the orientation of the Middle Atlantic Coast and its relationship to winds with easterly components, should have some correlation to the prolonged erosion experienced along the coastline but not necessarily with peak values of storm surges. Peak values of surge could have occurred in fast-moving coastal storms that only slightly affected the 5-day mean.

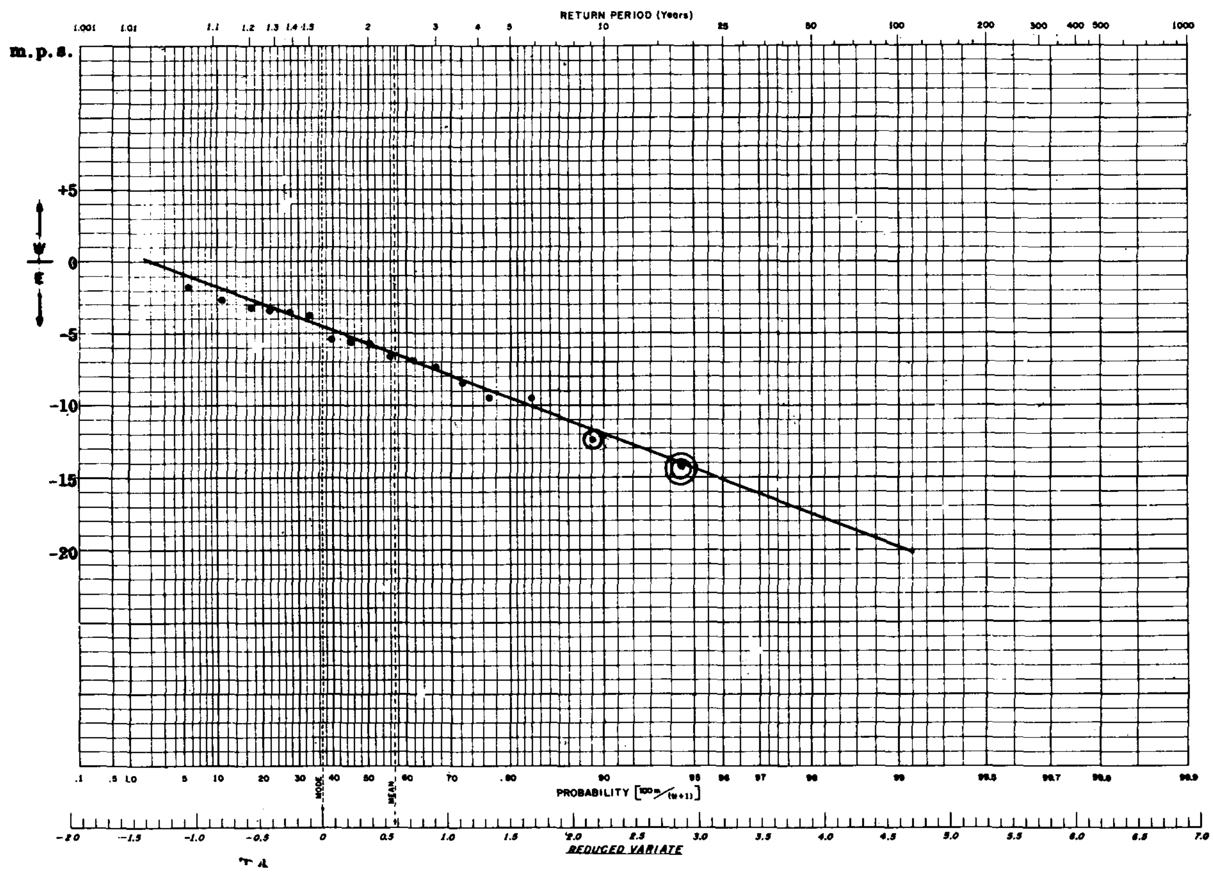

FIGURE 10.—Probability distribution of the annual extremes of 5-day mean maximum easterly flow between 35° and 45° N., from 55° to 75° W. Circled point=March 6–10, 1962; double-circled point, January 7–11, 1956.

Figure 10 shows the extreme value distribution of the easterly flow for this zone. The January 1956 case again has the highest value, −14.1 m.p.s., with the March 1962 storm close behind it with −12.4 m.p.s. The return periods are 18 and 11 years respectively.

The return period T, as used in extreme value theory, is defined as the average time distance between rare events [8]. The extreme value distribution has some very interesting peculiarities. The median is considerably smaller than the mean and, in fact, is $0.69T$. This means that there is a 50–50 chance that a 100-yr. event will occur within 69 years. On the other hand, the probability that the event will happen within the return period is only 0.63. The 100-yr. event therefore has only a 63 percent chance of happening at all within 100 years even though, on the average, it occurs once every 100 years.

From a knowledge of the properties of the extreme probability distribution, the probability $W(v)$ that an event with a return period T will occur within a given span of v years can be approximated by the equation

$$W(v) \approx 1 - \exp(-v/T)$$

when T is greater than about 10 years. The probability of having an easterly flow of the magnitude experienced during the March 1962 case, for which the return period was computed as 11 years, can therefore be estimated using the above equation for specific periods of 10 or 20 years.

$$W(10) = 1 - \exp(-10/11) = 0.60$$

$$W(20) = 1 - \exp(-20/11) = 0.84$$

Thus there is a 60 percent chance that the March 6–10, 1962 easterly flow will recur within a 10-yr. period, and an 84 percent chance for it to happen within a 20-yr. period.

As previously mentioned, the pressure gradient and therefore the easterly flow south of Cape Cod was stronger in the March case, while during the January storm the tighter gradient was over the areas north of Cape Cod, a coast which is more rugged. The storm surges experienced during the January 1956 storm were also from 1 to 2 ft. higher than during the March 1962 storm in places

TABLE 1.—*Storm surge heights (ft.)*

	March 1962	January 1956
Portland, Maine	1.6	2.6
Boston, Mass.	1.8	3.7
Sandy Hook, N.J.	5.2	4.0
Atlantic City, N.J.	4.7	4.0

north of Cape Cod such as Boston and Portland, while at Sandy Hook and Atlantic City they were about a foot lower (see table 1). Another important factor was that the March 1962 storm occurred at the maximum spring tide for the month, while the January 1956 storm occurred at the lower spring tide. This difference in the height between the low and high spring tides amounted to about 2 ft. at Portland, 1 ft. at Sandy Hook, and about ½ ft. at Hampton Roads, Va.

If the return period for the easterly flow is considered to be 18 years for the January storm and 11 years for the March storm, and if this flow is assumed independent of the lunar cycle, the return periods for similar flow occurring during a maximum spring tide are about 99 and 60 years respectively. Therefore, the probability of an easterly flow of the March 6–10, 1962 magnitude occurring in conjunction with a maximum spring tide is 15 percent for 10 years and 28 percent for 20 years.

4. CONCLUSIONS

The mean pressure values of the March 1962 storm were not markedly outstanding. In fact from the pressure extremes it would appear that the January 1956 storm should have been the storm of the century. While the return periods for the strength of the associated cyclone and anticyclone were 5 and 2 years, respectively, for the March 1962 storm, the corresponding values for the January 1956 storm were 600 years and 20 years. If the return periods for the easterly flow between 35° and 45° N. are taken as an index of the storm intensity, these storms compare more closely having an 18-yr. return period for the January storm and an 11-yr. period for the March storm.

However it becomes apparent from other aspects of the pressure patterns of these two storms why the March storm caused more severe damage along the Middle Atlantic Coast. The most outstanding feature of the March pattern is the uninterrupted fetch of winds with easterly components across the northern latitudes of the entire Atlantic, whereas in January 1956 there were two distinct low pressure cells separated by a strong ridge. This ridging is usually found in severe east coast extratropical cyclones, but did not occur in the March case because of the intense storm preceding it and the short distance between them. Another factor was a tighter pressure gradient in the March situation between the latitudes of Cape Cod and Cape Hatteras along the vulnerable Middle Atlantic Coast. Much of the strong gradient during the January storm was located over the Canadian Maritime Provinces and the northern New England coast. Finally, in addition to these two pressure features, the March storm occurred at maximum spring tide while the January storm occurred at the lower spring tide for the month.

ACKNOWLEDGMENTS

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